FIRST RESULTS FROM A MULTI-WAVELENGTH SURVEY OF QUASAR JETS

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We present results based on the first 20 *Chandra* images obtained in a survey of jets in radio selected flat-spectrum quasars (FSRQs), along with new sub-arcsecond radio maps and optical images. We discover jet X-ray flux in 12 sources despite short exposures, establishing that FSRQ jets are often X-ray bright. The X-ray morphology typically matches the radio and fades rapidly after the first sharp radio bend, but there are notable exceptions. Optical non-detections rule out simple synchrotron models for jet X-ray emission, implying these systems are dominated by inverse Compton (IC) scattering. Models of IC scattering of the cosmic microwave background (CMB) constrain the bulk flow and magnetic field, suggesting the jets are oriented close to our line of sight, with deprojected lengths often $\gg 100$ kpc.

We are conducting a survey of a large, flux-limited sample of FSRQs selected by extended 5 GHz flux ($> 2''$ from the core). The 56 sample members span a wide range of radio morphologies and redshifts. Of these, 20 were observed by *Chandra* during cycle 3[1]. New sub-arcsecond resolution radio maps for all 20 were obtained with *ATCA* and *VLA*, and six (so far) have been imaged with *Magellan*[2]. Results are summarized in Table 1.

X-ray jets are detected in 12/20 sources; a higher rate amongst the (radio) brighter jets suggests deeper X-ray observations would yield more detections. X-ray jets are one sided, with peaks usually coincident with radio knots up to the first sharp bend (Fig. 1). Low optical flux limits in five systems indicate that the synchrotron continua cut off below $\nu \sim 10^{14}$ Hz, suggesting that the X-ray flux is dominated by a different process. IC-CMB models[3] fit best, suggest bulk Lorentz factors $\Gamma \sim 3$–10 and magnetic fields $B_{\rm eq} \sim 10^{-5}$ Gauss, with jets directed within $\sim 20^\circ$ of our line of sight[1,4].

Table 1. Some results for the 20 targets observed during *Chandra* cycle 3.

Target name	z	Bj mag	A/B[a]	X-jet?[b]	$\alpha_{\mathrm{rx,jet}}$	g^c_{pred}	g^d_{obs}
PKS 0208–512	0.999	17.1	B	Y	$0.92 \pm .01$	23.4	>24.5
PKS 0229+131	2.059	17.7	B	N	> 0.95	$\cdots$	$\cdots$
PKS 0413–210	0.808	18.7	A/B	Y	$1.04 \pm .02$	23.2	$\cdots$
PKS 0745+241	0.410	19.0	B	N	> 0.91	$\cdots$	$\cdots$
PKS 0858–771	0.490	17.9	B	N	> 0.99	$\cdots$	>26.0
PKS 0903–573	0.695	19.0	A/B	Y	$1.07 \pm .02$	22.9	$\cdots$
PKS 0920–397	0.591	18.3	A	Y	$1.00 \pm .02$	23.4	$\cdots$
PKS 1030–357	1.455	19.5	B	Y	$0.93 \pm .01$	23.0	>26.0
PKS 1046–409	0.620	17.5	A/B	Y	$0.95 \pm .03$	24.5	>25.5
PKS 1145–676	?[e]	19.4	B	N	> 0.95	$\cdots$	$\cdots$
PKS 1202–262	0.789	19.8	A/B	Y	$0.86 \pm .01$	22.5	>26.7
PKS 1258–321	0.017	13.0	A	Y	$1.03 \pm .03$	23.7	$\cdots$
PKS 1343–601	0.013	10.8[f]	A/B	Y	$1.01 \pm .02$	23.3	$\cdots$
PKS 1424–418	1.522	18.0	B	N	> 0.91	$\cdots$	$\cdots$
PKS 1655+077	0.621	18.8	B	N	> 0.88	$\cdots$	$\cdots$
PKS 1655–776	0.094	17.5	A	N	> 1.07	$\cdots$	$\cdots$
TXS 1828+487	0.692	17.1	A	Y	$0.91 \pm .01$	21.9	$\cdots$
PKS 2052–474	1.489	18.2	B	N	> 0.89	$\cdots$	$\cdots$
PKS 2101–490	?[e]	17.1	B	Y	$0.99 \pm .02$	23.8	>25.3
PKS 2251+158	0.859	16.6	A/B	Y	$0.95 \pm .01$	22.4	$\cdots$

Note: [a] Membership in extended 5 GHz radio flux-limited (A) and/or morphologically-selected (B) subsamples. [b] Is jet detected in X-rays? [c] g' mag predicted by synchrotron model (using $\alpha_{\mathrm{rx,jet}}$). [d] Observed jet limiting mag (no optical detections). [e] z to be measured with *Magellan* in 2004. [f] Gunn z mag; Bj extinction $\sim$12 mag!

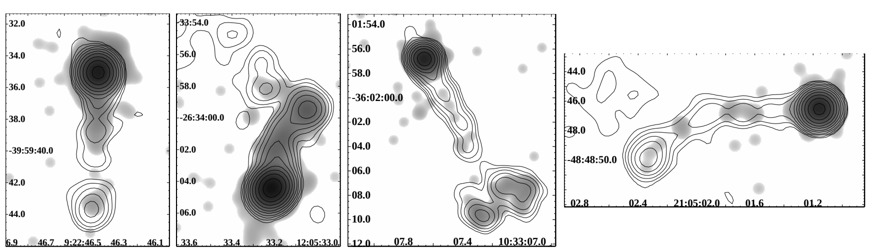

Figure 1. X-ray images with radio contour overlays for 0920–397, 1202–262, 1030–357 & 2101–490 (left to right). 0920 and 1202 are representative of most jet systems: the X-rays match the radio contours, fading rapidly after the sharp bend 5.6″ NNW of the core of 1202. Uniquely, the X-rays in 1030 remain strong through a sequence of sharp bends. 2101 is unusual in that the X-ray knots lie between the radio peaks.

References

1. H. Marshall *et al.*, *ApJS, submitted*; see http://space.mit.edu/~jonathan/jets.
2. J. Gelbord *et al.*, *in prep.*
3. F. Tavecchio *et al.*, *ApJ* **544**, L23 (2000).
4. D. Schwartz *et al.*, *New Astron. Rev.* **47**, 461 (2003).